GRAVITY MODELS FOR LUNAR MASCON BASINS: DISTRIBUTION AND THICKNESS OF MARE BASALTS AND BASIN EJECTA

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Lunar mascons are regions of positive gravity anomalies over topographic basins. First discovered by Doppler tracking of Lunar Orbiter [1], mascons are among the most prominent features in the lunar gravity field. Mascons are found at many of the near-side, circular mare basins, including Crisium, Humorum, Imbrium, Nectaris, Orientale, and Serenitatis. Acquisition of new, high resolution gravity and topography data sets by the Clementine spacecraft [2] allows a new look at the mass distributions that produce these gravity anomalies. Building on prior work [3], I examine the distribution and thickness of mare basalts and of basin ejecta implied by these gravity anomalies.

Mare Basalt Thickness

Because mascons are gravity highs in regions of topographic lows, they require the existence of excess mass somewhere in the structure of these impact basins. Two fundamentally different models have been proposed. In one, an uncompensated load is located close to the lunar surface [4], for example from the basalt fill found in all mascon basins. In the second, the excess mass occurs as super-isostatic relief at the crust-mantle boundary (or moho) [5]. Subsequent modeling has generally invoked some combination of these two processes [e.g., 6-9].

Here, I test a specific hypothesis for the origin of mascon gravity anomalies[3,8]: the impact basin itself is assumed to be isostatically compensated because of the high temperatures produced by the impact. There was generally a substantial time-lag between basin formation and basalt emplacement, allowing the lithosphere to cool and thicken prior to basalt emplacement. At the time of basalt emplacement, the elastic lithosphere thickness has been estimated to be from 40 to in excess of 75 km for the various mascon basins [10]. For the predominant wavelengths of basalt loading, these lithospheric thicknesses are large enough that the load will be largely uncompensated. With a sufficient basalt thickness, this can produce a positive gravity anomaly within a topographic low.

To test the hypothesis that mascons are produced by uncompensated mare basalts, I have performed a series of numerical simulations. I assume that the basement (sub-basalt fill) topography is Airy compensated and that the basalt fill is uncompensated, for the reasons outlined above. Collectively, the basement topography plus the basalt fill sum to the observed topography. The free-air gravity anomaly produced by this mass distribution is determined by integrating over the volume of density anomalies and then filtering to the resolution of observed gravity field. The basalt fill is assumed to have a constant thickness h from the center of the basin out to a radius of R_1. From R_1 to radius R_2, the basalt fill thickness is assumed to decrease linearly with distance from the basin center. From R_2 to the edge of the mare, a constant basalt fill thickness of 0.6 km is assumed, which is adopted as a typical value for the edge of a mare based on studies of partially filled craters [11,12]. The free parameters h, R_1, and R_2 are adjusted so that the model gravity anomaly matches observations [2]. Results for the major mascon basins are shown in Table 1. These results are derived using gravity model GLGM2 and topography model GLTM2A [2]. Ongoing efforts to refine the gravity field by relaxing the *a priori* constraints used in deriving the field [13] may slightly increase the amplitudes of the gravity anomalies over the mascon basins. If so, the required basalt fill thickness, h, will also increase.

The success of the proposed model can be tested by comparing the required basalt fill thicknesses with independent geologic estimates of the basalt thickness in these basins. One way to estimate the basalt thickness is from basin depth-diameter statistics [14,15]: basins that are abnormally shallow for their size are assumed to have sufficient basalt fill to account for the shallow depth. For Humorum, Imbrium, and Serenitatis, the basalt thickness required by the uncompensated basin fill gravity model is less than the geological estimates of basalt present in these basins [14,15]. Accordingly, for these basins super-isostatic uplift of the moho is not required to explain the gravity data, although such uplift is also not ruled out. This conclusion disagrees with a recent study [9] that found super-isostatic moho uplift for all six of the mascon basins modeled here. For Crisium, the basalt thickness estimates from the basin depth-diameter relationship range from 0.8 km [14] to 2.4 km [15], while Apollo Lunar Sounder Experiment observations indicate a basalt thickness of 2.4 to 3.4 km [16]. The latter two observations indicate that the basalt fill can account for most or perhaps all of the gravity anomaly, so that super-isostatic moho uplift is not required. For Nectaris, basin depth-diameter relationships indicate a basalt thickness of no more than 0.5 km [14,15]. A study of partially filled craters found a minimum basalt thickness of 1.5 km in Nectaris but could not determine the actual basalt thickness [11]. A definitive evaluation of the uncompensated basalt fill model for this mascon is not possible, but super-isostatic moho uplift may be needed here. Finally, for Orientale the actual basalt thickness [14,15] is certainly far less than required to explain the mascon by uncompensated basalt alone. Intrusive magmatism might explain some of the deficit, a possibility that is currently being assessed, but Orientale is presently the most likely candidate for super-isostatic moho uplift of any lunar mascon basin.

Table 1: Basalt Fill Parameters

	h (km)	R_1 (km)	R_2 (km)
Crisium	3.0	100	180
Humorum	3.2	75	185
Imbrium	2.5	140	270
Nectaris	2.7	120	160
Orientale	2.8	100	150
Serenitatis	3.1	100	240

The thickest portion of the model basalt fill lies between the basin center and radius R_1. For all basins shown in Table 1, R_1 is at or inside the innermost basin ring [17]. For Crisium, Imbrium, and Orientale, R_2 also is either at or slightly inside the innermost basin ring. For Nectaris and Serenitatis, R_2 is 35 to 40 km outside the first basin ring but well inside the second basin ring. For Humorum, R_2 is 15 km outside the second basin ring.

Basin Ejecta

In the region surrounding major impact basins, the effects of impact-induced fracturing of bedrock and the deposition of low density ejecta should produce a free-air gravity low. The presence of such low density material has been demonstrated for Orientale and Grimaldi using Lunar Orbiter and Apollo gravity data [7,18]. Otherwise, there has been little effort to explore this aspect of basin structure using gravity observations. Efforts are currently underway to use Clementine gravity and topography observations to better constrain the distribution and surface density of this low density material around the major mascon basins.

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